Nutritional values of raw and cooked 'calçots' (*Allium cepa* L. resprouts), a crop in expansion

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Abstract

BACKGROUND:

'Calçot' is the Catalan name for the immature floral stems of second-year onion resprouts of the *Blanca Tardana de Lleida* (BTL) landrace. Highly appreciated for their sensory attributes, these resprouts are typically consumed after roasting on an open fire. Now new preparations are appearing, helping to expand the market for 'calçots'. This study aimed to i) compare the nutritional and sensory characteristics of BTL 'calçots' versus other onion varieties, ii) analyze the effects of cooking and/or *in vitro* gastrointestinal digestion on the nutritional properties of 'calçots', and iii) determine the influence of the environment on the antioxidant properties of 'calçots'.

RESULTS:

Except some minerals, nutritional and sensory characteristics of both raw and cooked 'calçots' differed between varieties. Flavonoid content decreased 85% during cooking, and total phenolic content 30%. By contrast, antioxidant activity increased after cooking. Most traits had a nonlinear response to heating, and differences between

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varieties generally decreased after cooking. Location also had strong effects on antioxidant activity. *In vitro* digestion of cooked 'calçots' sharply decreased antioxidant activity after the intestinal phase. The only significant genotypic correlation between sensory and nutritional quality was sweetness with ash content (R=-0.97).

CONCLUSION:

Cooked BTL 'calçots' are within the limits of the onion domain for nutritional properties, and the variability reported for onion bulbs is also present in resprouts. The effects of the environment, cooking, and *in vitro* digestion clearly overlap the genetic effects.

Keywords: 'calçot', onion, nutritional description, bioaccessibility, antioxidant activity

1. Introduction

Onion (*Allium cepa* L.) is one of the world's oldest vegetable crops[1] and is the second most consumed vegetable, after tomato (*Solanum lycopersicum* L.).[2] Onions are versatile, used in many dishes and consumed in nearly all cultures.[3] Like all the crop species in the *Allium* genus, onions are good sources of nutrients.[4] They are a major source of polyphenols (secondary metabolites of plants with strong antioxidant activity) in human diet, and their high content of antioxidant flavonoids and frequent consumption make onions the major source of these healthful compounds in the Western European diet.[5,6] Numerous investigations into the composition of onions have found a wealth of healthful compounds,[3,4] and the concentration of these compounds varies widely depending on the variety, growth stage, and environmental conditions.[7] For example, colored varieties have larger concentrations of flavonoids.[8] Flavonoids are the major fraction of phenolics in onions,[9] thanks to two flavonoid subgroups: the anthocyanins, which give some varieties their red/purple color; and the flavanols, which give other varieties their yellow and brown skins.[3] Nevertheless, cooking can drastically

affect the amount and behavior of polyphenols in vegetables and can consequently influence their antioxidant capacity.[10]

The edible part commonly used in onions is the bulb harvested during the first season of the vegetative cycle, whether as a spring or dry onion. However, the resprouts that appear during the second season of the vegetative cycle are also consumed in Catalonia (Northeast Spain), where the consumption of 'calçots' is widely extended. 'Calçot' is the Catalan name for the immature floral stems that are produced by planting second-year onions and covering them with soil to whiten the edible part. They are typically consumed roasted on a hot open fire, often in popular celebrations called 'calçotades'. The *Ceba Blanca Tardana de Lleida* (BTL) landrace is commonly used for producing 'calçots', although all onion varieties produce resprouts, which vary in number, morphology, color, and sensory profile.[11,12] The annual market volume of 'calçots' is currently about €15 million, and the European Union has designated the Protected Geographical Indication 'Calçot de Valls'[13] for 'calçots' from the BTL landrace, that are produced in the traditional area of cultivation. This label boosts the regional economy and has expanded the demand for 'calçots' throughout Spain and in other parts of the world.

Consumers' increasing interest in healthy and quality foods, and the current trend to associate traditional food crops with health-promoting properties, have resulted in a growing demand for products with well-defined healthful characteristics due to their composition and origin. This strategy has been used to revalue typical food products, such as onions and long-shelf life tomato local landraces in Italy[14] or Dutch and Italian landraces of kale (*Brassica oleracea* ssp. acephala).[15]

Following this trend, 'calçot' producers are also interested in using the quality properties of their product to promote it. To this end, our group developed analytical

methods to describe the sensory profile of 'calçots', and to determine the influence of genetic and environmental factors on sensory and chemical quality traits.[11,16] Moreover, protocols to analyze the nutritional characteristics of 'calçots' have been developed and validated.[17]

The current study aimed to determine i) the nutritional and sensory characteristics of traditional BTL 'calçots' and compare them with those of 'calçots' from commercial onion varieties important in Spain; ii) the effects of cooking on the nutritional characteristics of 'calçots'; and iii) the influence of the environment on some nutritional characteristics, to complete a previous survey.[16]

2. Material and methods

2.1. Experimental design

This study comprised two field trials. The first (Experiment A) compared the nutritional and sensory characteristics of: 'calçots' from the traditional BTL variety versus 'calçots' from three other varieties of onion at a single location. The second (Experiment B) compared some nutritional characteristics of BTL in multiple locations.

The BTL landrace is characterized by late development, white skin and flesh, and a short shelf life. The improved BTL variety Montferri was used,[18] since it is now predominant in the PGI 'Calçot de Valls' for its high yield, 7.9 commercial 'calçots'/plant on average (PGI regulations define commercial 'calçot' as a resprout having a compact white edible base measuring 15–25 cm in length and 1.7–2.5 cm in diameter 5 cm from the root).[19] The three other long-day commercial varieties were Sabadell (brownish skin, purple flesh, and a long shelf-life), Babosa (golden skin, yellowish-white flesh, and a short shelf-life), and Figueres (light purple color and a medium shelf-life); these varieties yield between 1 and 2 commercial 'calçots'/plant.[12] All materials were obtained from the germplasm bank of the Miquel Agustí

Foundation/Barcelona School of Agricultural Engineering (BarcelonaTech); together with BTL, they are representative of the morphologic variation among Catalan varieties for the morphology at bulb and resprout level.

The four varieties were grown in a single location (Viladecans, 41°17′19.3″N 2°02′42.5″E, 18 masl), and the following variables were recorded: dry matter (DM), soluble solids content (SSC), pH, titratable acidity (TA), dietary fiber (DF), protein, ash, total phenolic content (TPC), flavonoid content, antioxidant activity, mineral composition, bioaccessibility, and sensory attributes.

The second experiment (Experiment B) studied the influence of the environment by comparing TPC, flavonoid content, and antioxidant activity in the Montferri BTL variety grown in 5 locations that represent standard 'calçot' production areas:[16]

- La Masó (41°13′41.0″N 1°13′33.6″E, 115 masl)
- Figuerola del Camp (41°22'20.9"N 1°16'06.8"E, 474 masl)
- Altafulla (41°08′46.7″N 1°22′58.7″E, 52 masl)
- Viladecans 1 (41°17′19.3″N 2°02′42.5″E, 18 masl)
- Viladecans 2 (41°17'20.1"N 2°02'36.3"E, 18 masl)

In both experiments, conducted during the season 2016-17, a three randomized block design was used, with 100 plants per plot. Bulb onions were replanted in September at a density of 31,000 plants per hectare with a 0.3 m x 0.75 m planting pattern. Experimental fields were located within commercial farms and managed by farmers using their own traditional techniques for fertilization, irrigation, weed control, and pest management.[20]

2.2. Sampling and processing

In all locations, 'calçots' were harvested in February when they reached the commercial stage of development. A sample of 150 'calçots' (a single plant yields several 'calçots') from each plot was split into two lots, one to be analyzed raw and the other cooked. Immediately after harvesting, leaf blades were cut 4 cm in length, roots were removed, and 'calçots' were cleaned with tap water to eliminate adhering soil. For the analyses on raw samples, 'calçots' were peeled, the two most external leaves were removed, and the upper part was cut off, leaving the edible lower white part. For the analyses on cooked samples, 'calçots' were roasted at 270 ºC for 18 min in a convection oven (SALVA Kwik-co), the two most external leaves were removed, and the upper part was cut off of each 'calçot', leaving the edible lower white part. The edible white part from each sub-sample was triturated with a mixer (Taurus BAPI 850), and the pureed samples were frozen with liquid nitrogen and stored at -80ºC until their analyses.

2.3. Analysis

2.3.1 Soluble solids content, titratable acidity, pH, and dry matter content

SSC was directly determined in the puree with a hand refractometer (Erma, Japan) and expressed as ºBrix. TA (expressed in equivalence of malic acid), pH, and DM were determined as described by Sans et al.[16]

2.3.2 Composition

Protein, expressed as g per 100 g of dry weight, was measured by the improved Kjeldahl method (AACC 46-11.02) after copper catalyst modification.[21]

DF was measured by the Englyst procedure, using a commercial kit (Englyst Fiberzym kit, Novo Nordisk Bioindustries, Surrey, U.K.). This approach, which has evolved from the principles laid down by Southgate,[22] uses enzymatic−chemical methods to measure DF as nonstarch polysaccharides.

To enable ash content to be determined according to AOAC method 923.03,[23] dried samples were ground to an average particle size < 0.4 mm to obtain a flour; then 1 g of flour was burned in a muffle at 450 °C for 4 h. Ash extract was obtained by dissolving the ashes in 7.5 mL of 3 M nitric acid solution, heating, filtering, and adding water to make 50 mL. Minerals (P, Na, K, Ca, Mg, Mn, Fe, Cu, Zn) in diluted ash extract were analyzed by inductively coupled plasma optical emission spectrometry (ICP-OES) (Optima 3200RL, Perkin-Elmer, Norwalk, CT).

2.3.3 Total phenolic and flavonoid content

TPC was determined by the Folin–Ciocalteu method[24] with modifications.[25] Results were expressed as gallic acid equivalent. Flavonoids were extracted and total flavonoids were determined with the methods described by Santas et al.[26] and following the modifications described by Zudaire et al.[17] The results were expressed as quercetin equivalent.

2.3.4 Antioxidant activity

Due to the complex nature of phytochemicals, following Chu et al. recommendations,[27] antioxidant activity was analyzed by two methods: 2.2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging assay and ferric reducing antioxidant power (FRAP) assay. The extraction and determination were carried out as described by Plaza et al.[28] Results were expressed ascorbic acid equivalent.

All measurements were done in triplicate.

2.3.5 Bioaccessibility after simulated gastrointestinal digestion

Bioaccessibility is the amount of nutrients available in the intestinal brush border for transport into the cell.[29] To study the bioaccessibility of phenols and how digestion affects the activity of antioxidants from 'calçots', gastrointestinal digestion *in vitro* was simulated using the method described by Zudaire et al..[17] This method consists of three

sequential stages: an oral phase (pH 7, containing α-amylase), a gastric phase (pH 3, containing pepsin), and an intestinal phase (pH 7, containing pancreatin and fresh bile). Each sample was 'digested' in triplicate, and a blank sample was prepared following the same procedure but using only distilled water instead of 'calçot' sample. TPC and antioxidant activity (FRAP and DPPH) were determined with previously described methods after the gastric and intestinal phases.

2.3.6 Sensory analysis

Sensory analysis was carried out as described by Simó et al.[11] in a room designed for sensory tests that fulfilled the standards set out by the International Organization for Standardization.[30] Samples were submitted to a panel consisting of 8 trained judges and were evaluated in duplicate. Only the cooked samples were analyzed, as 'calçots' are not normally consumed raw. The intensity of organoleptic descriptors (sweetness, fiber perception, and off-flavors) was scored on a continuous 10 cm semi-structured scale and then transformed into numeric variables between 0 (low intensity of perception) and 10 (high intensity of perception).

2.4 Statistical analysis

All data were processed by analysis of variance (ANOVA), according to the following linear models:

In Experiment A, for nutritional attributes, $X_{ij} = \mu + v_i + s_j + v_i s_j + \varepsilon_{ij}$, and for sensory attributes, $X_{ij} = \mu + v_i + p_j + v_i p_j + \varepsilon_{ij}$. In Experiment B, $X_{ij} = \mu + l_i + s_j + l_i s_j + \varepsilon_{ij}$, where v, s, p, and l are the factors variety, state, panelist and location respectively.

When significant effects were observed, means were compared by calculating the least significant difference (LSD) ($P < 0.05$). Pearson's correlation coefficient and regression were used to study the relations among nutritional and sensory traits. Principal

components analysis (PCA) analysis was also used to facilitate synthetic discussion. The R statistic software was used for all statistical calculations.[31]

3. Results

3.1. Nutritional characteristics of 'calçots'

The ANOVA showed significant differences among the varieties for all the nutritional parameters except the content of some minerals (K, Mg, Mn, Fe, and Cu) (Table 1), indicating genetic variability among the onion resprouts examined. Furthermore, cooking significantly influenced ($P < 0.05$) all parameters except ash, and K, Mg, Cu and Zn content. The interaction variety x state (raw vs. cooked) was also significant for most traits, showing the varieties had a nonlinear response to the cooking process (Table 1).

In raw samples (Table 2), DM and SSC were intermediate in BTL 'calçots' (9.78 g/100g and 7.7 ºBrix), being significantly higher in Sabadell 'calçots' (10.22 g/100g and 8.0 ºBrix) and lower in Babosa 'calçots' (8.88 g/100g and 6.6 ºBrix). The parameter pH was significantly lower in Babosa (5.57) and BTL (5.58) than in Figueres (5.73) and Sabadell (5.83), but the range for this variable was small. The only significant difference among varieties in TA and DF was lower TA and higher DF for 'calçots' of the Babosa variety. BTL also had low protein and ash content, while Babosa was the most different, with higher values for these two parameters. BTL 'calçots' had the lowest values of TPC and flavonoids, as well as the lowest antioxidant activity, together with Sabadell variety. The parameter with the greatest differences between varieties in raw samples was flavonoid content, ranging from 0.738 g/kg in BTL to 8.225 g/kg in Babosa. Babosa 'calçots' had the highest values of phenolic content in raw samples (Table 2).

The main mineral component of 'calçots' was potassium, followed by calcium, phosphorus, sodium, and magnesium; the other minerals determined were found in lower concentrations (Table 2).

PCA on nutritional characteristics was performed separately in raw and cooked samples (Figure 1). In the raw state, BTL was quite close to Figueres, and both these varieties were clearly separate from Sabadell and Babosa (Figure 1a). In the cooked state, the varieties were also different, but the BTL position was clearly separate from the other varieties on the first axis, with the other three varieties separating on the second axis (Figure 1b).

The cooking process had a strong impact on the composition of 'calçots' (Table 2). Flavonoid content was the most affected parameter, decreasing 82.5% on average; TPC decreased 30.2% on average (on a dry weight basis). By contrast, antioxidant activity increased after cooking according to both FRAP and DPPH measurements. Roasting the 'calçots' increased DM, SSC, pH, TA, and protein content, but decreased DF. Ash content was not affected by the cooking process, although some of the minerals (especially Na) showed significant variations.

As mentioned above, the cooking process did not affect the composition of the varieties linearly (Table 1). On most of the parameters studied, cooked BTL 'calçots' were significantly different from the other three varieties (Table 2); BTL had the highest values of DM and SSC and the lowest of DF, protein, and ash content. BTL also had low values for TPC and flavonoids, but the differences among varieties were small in cooked material compared to those found in raw 'calçots'.

3.2. Total phenol content and antioxidant activity after *in vitro* digestion

Simulated gastrointestinal digestion increased TPC in all the varieties (Figure 2). However, *in vitro* digestion affected raw and cooked samples differently. In the raw

samples of ‘calçots’, except in the Sabadell variety, TPC after the gastric phase did not differ from the values found in undigested material, but TPC was significantly higher after the intestinal phase in all the varieties. In cooked samples, TPC was significantly higher after the gastric phase in all the varieties. Furthermore, the increases after the intestinal phase were proportionally higher in raw calçots.

Raw ‘calçots’ of the Babosa variety had higher TPC in digested samples, although TPC values overlapped with those of the Sabadell variety. In contrast, after the digestion of cooked samples, there were no significant differences in TPC between varieties.

The DPPH and FRAP measurements of antioxidant activity after in vitro gastrointestinal digestion, yielded results that followed similar patterns (Figure 3 and Figure 4). In cooked samples, antioxidant activity remained more or less constant after the gastric phase in all the varieties and decreased drastically after the intestinal phase. In contrast, in raw samples, antioxidant activity differed depending on the variety and the method of analysis.

3.3 Sensory analysis

ANOVA showed significant differences ($P < 0.05$) for the three traits evaluated. The factor panelist was also significant for the three sensory traits considered, but none of the variety x panelist interactions were significant (data not shown). The four varieties showed different sensory profiles (Figure 5). For sweetness, BTL ‘calçots’ had the highest values, being the only variety with a mean value greater than 5, and the Sabadell variety had the lowest values. For fiber perception, BTL had the lowest values (mean 0.59), and Figueres had the highest value (mean 2.05). For off-flavors, the only variety that was significantly different was Sabadell, which had the highest values.

Although the number of cases analyzed is low, the correlation among nutritional and sensory traits was studied; the only significant genotypic correlation ($P<0.05$) between sensory and nutritive quality was between sweetness and ash content ($R=-0.97$).

3.4 Location effect

In the second experiment, which focused solely on BTL 'calçots', the ANOVA showed the location factor as responsible for significant differences in all the traits considered (Table 3). These results are congruent with those presented for the BTL 'calçots' in section 3.1, and they underline the great influence of the environment in traits related with antioxidant activity.

In general, the variation among locations was larger in raw samples, except for antioxidant activity measured with the DPPH method (Table 3). Again cooking smoothes differences. In both raw and cooked samples, the trait with the greatest variation among locations was flavonoid content.

4. Discussion

To our knowledge, the present study is the first to report some nutritive traits (protein, DF, and mineral contents) in second-year onion resprouts ('calçots'). For the other parameters evaluated, the orders of magnitude found here were similar to those reported previously in other studies.[16,17,26]

4.1. Comparison between onions and 'calçots'

The composition of 'calçots' was within the range reported for first year bulb onions. For example, the results for 'calçots' in the raw state are within the range of variation reported for onions for DM, SSC, TPC, flavonoid content, and antioxidant activity measured by FRAP and DPPH, with BTL 'calçots' being in the lower extreme.[9,32] Petropoulos et al., who compared a local onion landrace from Greece with three other varieties, found higher values of DM and SSC, but less protein and similar ash content

than in 'calçots'.[33] The mineral composition of the 'calçots' in this study is similar to that found in onions, although the potassium levels are more similar to those of spring onions than of dry onions.[34]

4.2. BTL profile

Although the composition of 'calçots' from the four varieties is within the limits of the first year bulb onion domain, the varieties had different profiles in both the raw and cooked states (Table 2 and Figure 1). This is especially relevant for breeding, because variability among BTL accessions for chemical composition is low.[16] The wide dispersion of the varieties in the PCA biplot planes reflects the variability among them, especially in the raw state (Figure 1a). In the cooked state in which 'calçots' are normally consumed, BTL 'calçots' are characterized by high DM, high SSC, low DF, low flavonoid content, and low antioxidant activity (Figure 1b).

The levels of TPC in BTL 'calçots' were in line with those reported in previous studies.[17,26] The low level of flavonoids was expected, because BTL is completely white. Compared to red and yellow varieties, white varieties have lower levels of these molecules that are responsible for external color.

Although DPPH estimations were lower than FRAP ones, this is common in the literature.[6,32] After *in vitro* digestion, FRAP and DPPH both indicated that cooked BTL 'calçots' had the same TPC as the other varieties (Figure 2, Figure 3 and Figure 4). In fact, antioxidant activity decreased sharply during *in vitro* digestion in all varieties; this was especially true in cooked 'calçots', whereas in raw 'calçots' the decrease varied with the variety and stage of digestion. As heat changes the biological activity of many molecules, the nonlinear behavior of the varieties and analytical methods in raw materials is attributable to the complexity of the chemical matrix in raw calçots. Somehow, the cooking process tends to smooth out differences among varieties and

between the two methods of measurements. These findings are in agreement with other reports, where bioaccessibility after *in vitro* digestion varies depending on the matrix evaluated. For example, in a study evaluating TPC and antioxidant activity after the *in vitro* digestion of 33 raw fruits, Chen et al. reported that, depending on the fruit, both parameters increase, decrease, or remain unchanged after digestion.[35]

The only significant genotypic correlation between sensory and nutritional qualities was between ash content and sweetness (R=-0.97). So, increasing the other nutritive parameters in BTL without decreasing its sensory quality seems possible by means of crossings with other varieties.

4.3. Effects of cooking on 'calçots'

The main effect of cooking on the nutritional characteristics of the 'calçots' was to increase most parameters, except DF, TPC, flavonoids, Ca, and Na, which decreased significantly (Table 2). In BTL, the pattern of effects was similar to that of the average of all varieties, but the decrease in flavonoid content was much smaller (82.52% in average vs. 10.43% in BTL), as the starting point before roasting was already very low (Table 2). Thus, in general, cooking increased the content of the main nutrients except DF, Ca, and Na, but decreased the content of molecules with reported antioxidant properties, such as phenols in general and flavonoids in particular. Nevertheless, antioxidant activity as measured by both FRAP an DPPH increased. This increase could be attributed to the liberation of antioxidant compounds from insoluble portions or to the formation of novel compounds with antioxidant capacities during the cooking process.[17]

Conflicting results about the effects of cooking on nutritional content have been found in other studies, depending on the vegetable and the cooking method applied. The results obtained agree with those of other studies that found a reduction of TPC in other

Alliums such as garlic (*Allium sativum* L.) heated to 100ºC[36] or leek (*Allium ampeloprasum* L. var. *porrum*) after boiling.[10] However, our results contrast with those reported by Sharma et al.,[37] who found significantly increased TPC after heating in six onion varieties, although the total flavonoid content decreased. Furthermore, Turkmen et al. found that cooking decreased TPC in some vegetables such as squash (*Cucurbita pepo* L.), peas (*Pisum sativum* L.), and leek, but increased it in pepper (*Capsicum annuum* L.), broccoli (*Brassica oleracea* L. var *italica)*, and green beans (*Phaseolus vulgaris* L.); antioxidant activity increased or remained unchanged depending on the vegetable.[38] Sengul et al. also found that TPC varied in different ways depending on the vegetable and the cooking method evaluated.[39]

Thus, the significant interactions between variety and cooking in our study (Table 1 and Table 2) are in line with the nonlinear responses for different types of vegetables and cooking methods observed in other studies.

4.4. Environmental effects

In this study, the environment had significant effects on both antioxidant activity and the content of the compounds involved in this activity (Table 3), although on average, with the exception of TPC, the effects of cooking were similar to those found in the experiment with the four varieties at a single location (Table 1 and 2). Ren et al.[6] reported similar results, underlining the complexity of regulation of bioactive compounds in crop plants, which respond differently to the growing environment. No significant associations were found between the locations' specific soil and climatic parameters on the one hand and antioxidant activity and/or molecules involved in this activity on the other (data not shown). A previous study on chemical and sensory characteristics of BTL 'calçots' also found difficult to associate them with specific environmental factors.[16]

5. Conclusions

Farmers, consumers, and breeders have guided the evolution of BTL 'calçots' toward an ideotype characterized by a high number of resprouts per onion that are sweet, have low perceptibility of fiber, and are free of off flavors. This study shows that the nutritional properties of cooked BTL 'calçots' (the state in which they are commonly consumed) are similar to those previously reported for first year bulb onions, and that the variability reported in onion bulbs is also present in these resprouts.

Thus, in addition to the cultural, productive, and sensory characteristics that are driving the expansion of the market for 'calçots', cooked BTL 'calçots' provide all the health benefits provided by cooked first year bulb onions. Given the genetic variability at the resprout level and the absence of strong negative genetic correlations between nutritive characteristics and the ideotype traits, breeding to increase nutritional quality without affecting the ideotype seems possible. Furthermore, as in previous studies on chemical characteristics, environmental factors had important effects on the amounts of flavonoids and other phenolic compounds as well as on antioxidant activity.

Finally, the results obtained suggest that it is important for breeding programs for nutritional characteristics to take the bioavailability of the compounds into account, as evidenced for instance, by the dramatic decrease in antioxidant activity after *in vitro* gastrointestinal digestion and the smoothing of the differences in nutritional parameters between varieties after cooking. The real value of some parameters at the cellular level is even more complex to evaluate than sensory value. Therefore, the figures that really impact consumers' health might be less spectacular than those obtained for raw and undigested onions.

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Conflict of interest

None.

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Table 1 Significance code of the factors variety (BTL, Sabadell, Figueres and Babosa), state (raw and cooked), and interaction in the ANOVA (Experiment A).

Parameter	**Sign. F variety**	**Sign. F state**	**Sign. F v x s**
DM (g/100g f.w.)	***	***	***
SSC (ºBrix)	***	***	***
pH	**	***	***
TA (g/100g f.w.)	***	***	NS
DF (g/100g d.w.)	**	***	*

Protein (g/100g d.w.)	***	***	NS
Ash (g/100g d.w.)	***	NS	***
TPC (g/kg d.w.)	***	***	***
FRAP (mol/ kg d.w.)	***	***	***
DPPH (mol/ kg d.w.)	***	***	***
Flavonoids (g/kg d.w.)	***	***	***
P (g/kg d.w.)	NS	***	NS
Na (g/kg d.w.)	***	***	**
K (g/kg d.w.)	NS	NS	NS
Ca (g/kg d.w.)	**	***	***
Mg (g/kg d.w.)	NS	NS	NS
Mn (g/kg d.w.)	NS	*	NS
Fe (g/kg d.w.)	NS	*	NS
Cu (g/kg d.w.)	NS	NS	NS
Zn (g/kg d.w.)	*	NS	*

NS: non-significant (P≥ 0.05), *: significant at P< 0.05, **: significant at P< 0.01, and ***: significant at P< 0.001. f.w., fresh weight, d.w., dry weight. DM, dry matter content; SSC, solid soluble content; TA, titrable acidity; DF; dietary fiber; TPC, total polyphenol content; FRAP, antioxidant activity measured by ferric reducing antioxidant power; DPPH, antioxidant activity measured by 2.2-diphenyl-1-picrylhydrazyl.

Table 2 Mean values for the variety and state effect in the nutritional traits of 'calçots' (Experiment A).

	Raw				Cooked				Average	
Parameter	**BTL**	**Sabadell**	**Figueres**	**Babosa**	**BTL**	**Sabadell**	**Figueres**	**Babosa**	**Raw**	**Cooked**
DM (g/100g f.w.)	9.78 b	10.22 a	9.75 b	8.88 c	12.30 a	11.82 b	11.42 c	10.91 d	9.66 b	11.61 a
SSC (ºBrix)	7.7 b	8.0 a	7.7 b	6.6 c	9.6 a	8.7 b	8.6 b	8.0 c	7.5 b	8.7 a
pH	5.58 b	5.83 a	5.73 a	5.57 b	6.33 ab	6.21 c	6.35 a	6.29 b	5.68 b	6.29 a
TA (g/100g f.w.)	0.133 a	0.144 a	0.133 a	0.108 b	0.158 b	0.178 a	0.158 b	0.134 c	0.130 b	0.157 a
DF (g/100g d.w.)	17.70 b	16.97 b	17.14 b	19.47 a	12.92 b	14.42 a	14.86 a	14.68 a	17.82 a	14.22 b
Protein (g/100g d.w.)	18.13 c	22.39 a	20.46 b	18.79 c	19.57 c	25.95 a	23.04 b	21.94 b	19.94 b	22.63 a
Ash (g/100g d.w.)	5.96 c	6.67 b	5.72 c	7.07 a	5.60 c	6.77 a	6.29 b	6.43 ab	6.35 a	6.27 a
TPC (g/kg d.w.)	2.972 c	4.871 b	4.681 b	5.366 a	2.516 b	3.222 a	3.225 a	3.514 a	4.472 a	3.119 b
FRAP (mol/ kg d.w.)	0.013 c	0.012 c	0.017 b	0.019 a	0.015 c	0.023 b	0.022 b	0.025 a	0.016 b	0.021 a
DPPH (mol/ kg d.w.)	0.009 b	0.009 b	0.013 a	0.013 a	0.013 c	0.021 ab	0.019 b	0.023 a	0.011 b	0.019 a
Flavonoids (g/kg d.w.)	0.738 c	5.724 b	5.559 b	8.255 a	0.661 b	0.981 a	0.724 b	1.177 a	5.069 a	0.886 b
P (g/kg d.w.)	3.082 b	3.522 a	3.548 a	2.997 b	4.303 a	4.481 a	4.889 a	4.162 a	3.287 b	4.459 a
Na (g/kg d.w.)	1.607 b	2.478 a	1.312 c	2.483 a	1.026 a	1.441 a	1.090 a	1.407 a	1.970 a	1.241 b
K (g/kg d.w.)	22.419 c	24.517 b	22.912 c	26.838 a	23.452 a	24.281 a	26.154 a	24.199 a	24.171 a	24.522 a
Ca (g/kg d.w.)	3.996 b	4.584 a	3.163 c	3.963 b	1.763 a	2.001 a	2.118 a	1.703 a	3.927 a	1.896 b
Mg (g/kg d.w.)	1.068 c	1.257 a	1.114 bc	1.206 ab	1.168 a	1.212 a	1.346 a	1.220 a	1.161 a	1.237 a
Mn (g/kg d.w.)	0.010 a	0.010 a	0.009 a	0.009 a	0.010 a	0.010 a	0.011 a	0.011 a	0.009 b	0.010 a
Fe (g/kg d.w.)	0.030 a	0.041 a	0.036 a	0.042 a	0.028 a	0.030 a	0.034 a	0.026 a	0.037 a	0.030 b
Cu (g/kg d.w.)	0.016 a	0.020 a	0.015 a	0.018 a	0.017 a	0.016 a	0.025 a	0.021 a	0.017 a	0.020 a
Zn (g/kg d.w.)	0.022 c	0.027 b	0.027 b	0.030 a	0.027 ab	0.029 ab	0.032 a	0.024 b	0.026 a	0.028 a

Within rows and state (separately raw, cooked and average), means followed by the same letter were not significantly different at P < 0.05 (least significant difference test). f.w., fresh weight, d.w., dry weight.

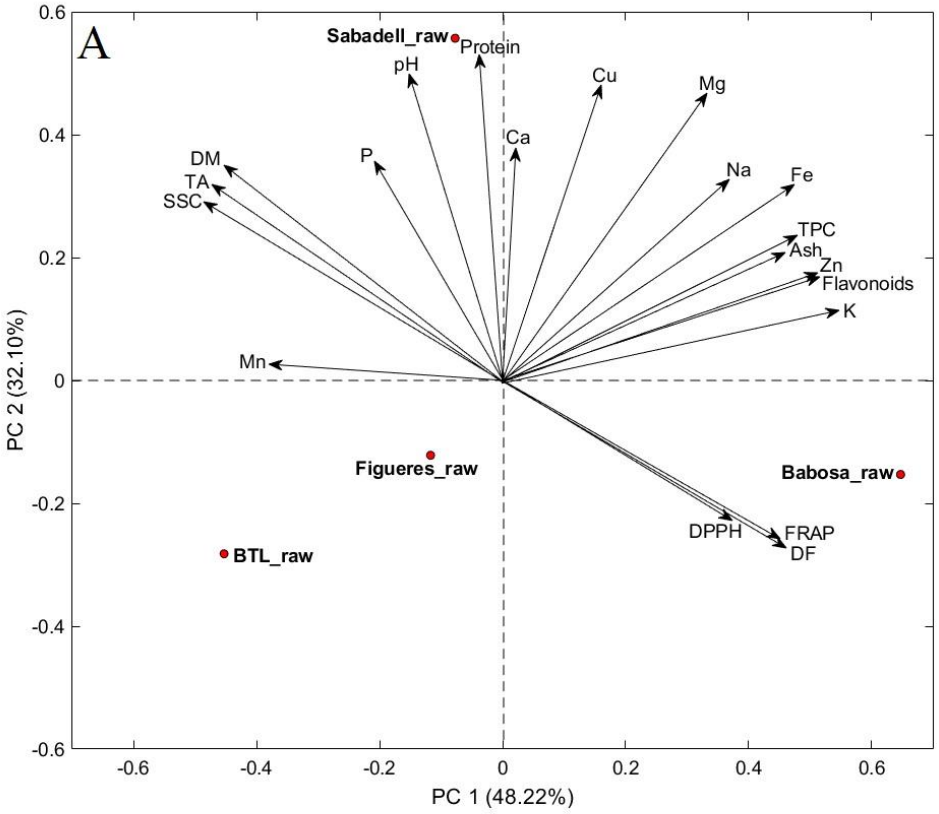
DM, dry matter content; SSC, solid soluble content; TA, titrable acidity; DF; dietary fiber; TPC, total polyphenol content; FRAP, antioxidant activity measured by ferric reducing antioxidant power; DPPH, antioxidant activity measured by 2.2-diphenyl-1-picrylhydrazyl.

Table 3 Mean values of the different parameters in the different locations and states in the BTL 'calçots'.

	TPC (g/kg d.w.)		**FRAP** (mol/ kg d.w.)		**DPPH** (mol/ kg d.w.)		**Flavonoids** (g/kg d.w.)	
Location	**Raw**	**Cooked**	**Raw**	**Cooked**	**Raw**	**Cooked**	**Raw**	**Cooked**
La Masó	2.886 a	2.733 ab	0.012 a	0.019 a	0.010 a	0.018 a	1.202 a	0.907 a
Figuerola	1.693 b	1.980 c	0.008 c	0.013 c	0.007 d	0.012 c	0.503 c	0.442 c
Altafulla	1.917 b	1.854 c	0.009 b	0.014 bc	0.009 bc	0.013 c	0.765 b	0.495 c
Viladecans	2.543 a	2.874 a	0.008 bc	0.015 b	0.008 cd	0.016 b	0.799 b	0.694 b
Viladecans 2	2.972 a	2.516 b	0.013 a	0.015 b	0.009 b	0.013 c	0.738 b	0.661 b
Variation among locations	75.55%	55.02%	62.50%	46.15%	42.86%	50.00%	138.97%	105.20%
Mean	2.402 a	2.391 a	0.010 b	0.015 a	0.008 b	0.014 a	0.804 a	0.650 b
Variation between raw and cooked	-0.45%		50.00%		75.00%		-19.15%	

In the comparison between locations, means of a column followed by the same letter are not significantly different at a $P < 0.05$ (least significant difference test). In the Mean of all locations, figures of a single parameter followed by the same letter indicate that mean of raw and cooked calçots are not significantly different at a $P < 0.05$ (least significant difference test). d.w., dry weight; TPC, total polyphenol content; FRAP, antioxidant activity measured by ferric reducing antioxidant power; DPPH, antioxidant activity measured by 2.2-diphenyl-1-picrylhydrazyl.

Figure 1 Biplot of the four varieties in the plane determined by the first two axes of the PCA considering all the nutritional parameters studied in the raw (A) and cooked (B) 'calçots' (Experiment A). The angle of the vector with the axes indicates the correlation between the principal component and the original variable, and its length is proportional to the variability in the original variable explained by each principal component. The percentages between parentheses refer to the variation explained by each principal component. DM, dry matter content; SSC, solid soluble content; TA, titrable acidity; DF; dietary fiber; TPC, total polyphenol content; FRAP, antioxidant activity measured by ferric reducing antioxidant power; DPPH, antioxidant activity measured by 2.2-diphenyl-1-picrylhydrazyl.



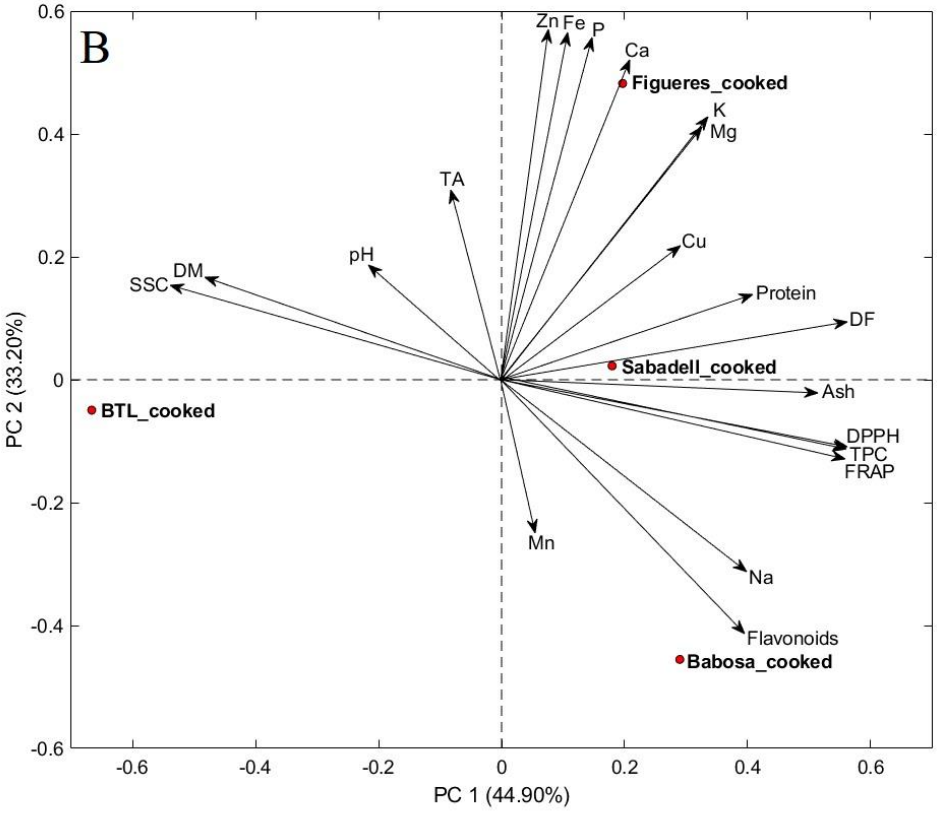


Figure 2 Total phenolic content after *in vitro* simulated gastrointestinal digestion (Experiment A). Values are expressed as mean ± standard deviation. Capital letters indicate significant differences ($P < 0.05$, least significant difference test) between samples at same digestion phase. Lower case letters indicate significant differences ($P < 0.05$, least significant difference test) between phases of *in vitro* simulated gastrointestinal digestion in a sample.

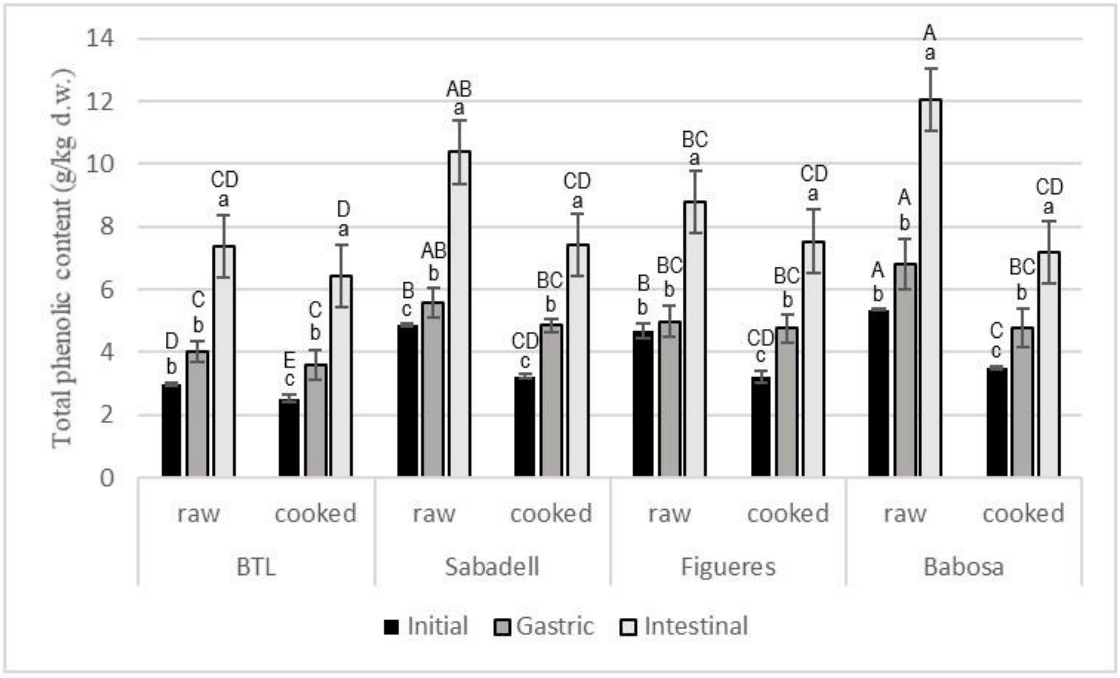


Figure 3 Antioxidant activity (FRAP) after *in vitro* simulated gastrointestinal digestion (Experiment A). Values are expressed as mean ± standard deviation. Capital letters indicate significant differences ($P < 0.05$, least significant difference test) between samples at same digestion phase. Lower case letters indicate significant differences ($P < 0.05$, least significant difference test) between phases of *in vitro* simulated gastrointestinal digestion in a sample.

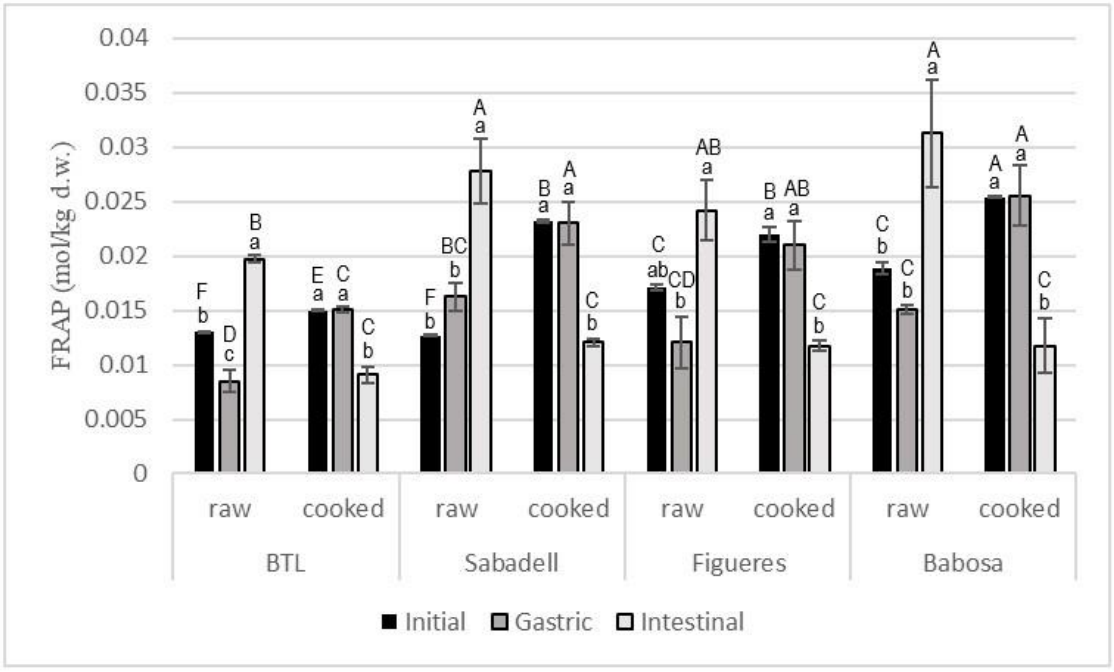


Figure 4 Antioxidant activity (DPPH) after *in vitro* simulated gastrointestinal digestion (Experiment A). Values are expressed as mean ± standard deviation. Capital letters indicate significant differences ($P < 0.05$, least significant difference test) between samples at same digestion phase. Lower case letters indicate significant differences ($P < 0.05$, least significant difference test) between phases of *in vitro* simulated gastrointestinal digestion in a sample.

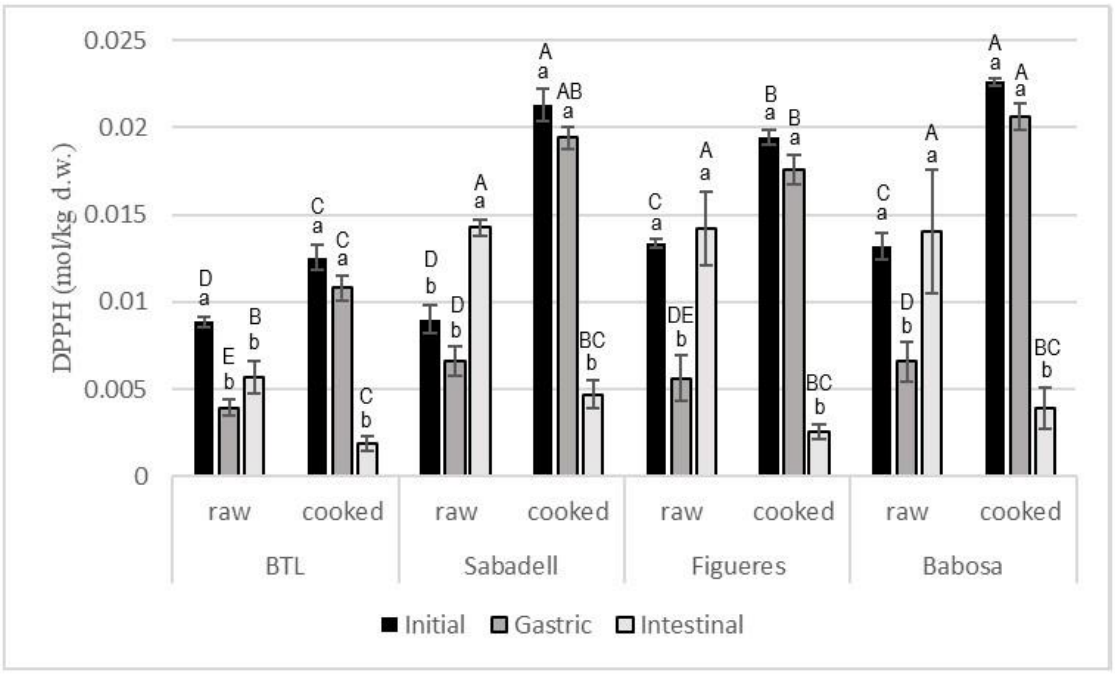


Figure 5 Results of sensory analysis (Experiment A). Values are expressed as mean ± standard deviation. Lower case letters indicate significant differences ($P < 0.05$, least significant difference test) between samples in each attribute.